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A Comparison of the Impacts of Aspects of Prospect Theory on WTP/WTAEstimated in Preference and WTP/WTA Space

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The importance of willingness to pay (WTP) and its counterpart willingness to accept (WTA), in the evaluation of policy measures has led to a constant stream of research examining survey methods and model specifications seeking to capture and explain the concept of marginal rates of substitution as much as possible. Stated choice experiments pivoted around a reference alternative allow the specification of discrete choice models to accommodate aspects of Prospect Theory, in the particular reference dependence. This permits an investigation of theories related to loss aversion and diminishing sensitivitywidely documented within the literature. This paper seeks to examine a number of theoretical developments. In particular, the paper seeks to empirically examine a number of aspects related to decision making processes that are posited to exist by Prospect Theory, namely reference dependence, loss aversion and diminishing sensitivities. Unlike previous research which has examined these issues in the past, we examine these assumptions on WTP/WTA rather than on the marginal utilities of decision makers. In doing this, the paper simultaneously compares and contrasts different econometric forms, in particular estimating models in preference space with WTP/WTAs calculated post estimation versus models estimated directly in WTP/WTA space where WTP/WTAvalues are directly during estimation. We find evidence for reference dependence and loss aversion in WTP/WTA for different time attributes, however we find less compelling evidence for the existence of diminishing WTP/WTAs.

Keywords: choice experiments; willingness to pay/willingness to accept space; preference space; preference asymmetry; reference dependence; loss aversion and diminishing sensitivities; prospect theory

1. Introduction

A recent spate of studies in the transportation literature has sought to incorporate Prospect Theory, or parts thereof, into the models used to explain traveller behaviour (see e.g., Avineri and

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Prashker, 2005; Cherchi, 2009; Li and Hensher, *in press*; Schwanen and Ettema, 2009; or van de Kaa, 2008 for a review of Prospect Theory in transportation research). This has resulted in a growing move away from the traditional expected utility framework often assumed in models of choice behaviour (e.g., De Palma et al., 2008).

Prospect Theory as originally posited by Kahneman and Tversky (1979) provide five key features underlying choice behaviour including that decision makers (i) first *frame (or edit) the offered prospects* (i.e., alternatives) by coding them as gains and losses relative to a reference point, and successively evaluate these edited prospects and then choose the prospect of highest value; (ii) use *reference dependence* to recognize different value functions for gains and losses with respect to the reference point rather than a utility function defined in Expected Utility models; (iii) have *diminishing sensitivity* associated withdecreasing marginal value of both gains and losses; (iv) suffer from *loss aversion* defined such that the disutility of a loss is valued higher than the utility of an equivalent gain; and (v) psychologically use non-linear probability weighting to transform the original probabilities. Cumulative Prospect Theory (Tversky and Kahneman, 1992) extended the original Prospect Theory by allowing for the possibility that probabilities may be transformed or influenced by the rank of the (attribute) outcomes in terms of preference. Under Cumulative Prospect Theory, the functional form for the decision weights is specified in line with Rank-Dependent Utility Theory (Quiggin, 1982).

As such, a model that fully incorporates all aspects of Prospect Theory must incorporate at a minimum, (i) *reference dependence*, i.e., separate value functions defined over gains and losses;(ii) *diminishing sensitive* (i.e., the curvatures of value functions suggesting decreasing marginal value of both gains and losses)and *loss aversion*; and (iii) *non-linear probability weighting*. Since the formalization of prospect theory however, must studies have tended to examine only certain aspects of the theory. In particular, a particular interpretation of reference dependence[3] has been tested in several studies through the use of different interview procedures, with particular reference to contingent evaluation (e.g., Bishop and Heberlein, 1979; Rowe et al., 1980), laboratory experiments (e.g., Bateman et al., 1997) and more recently, stated choice experiments (e.g., De Borger and Fosgerau, 2008; Hess et al., 2008; Hjorth and Fosgerau, 2009; Lanz et al., 2009; Masiero and Hensher, 2009). In all cases, independent of the specific methodology employed, reference dependency has been found to exist.

Despite numerous data collection methods being utilised as outlined above, stated choice experiments (SCE) currently represent the primary method for collecting data for the purpose of analysing and understanding choice behaviour. These experiments present surveyed respondents with hypothetical choice situations with the resulting model estimation relying on the Random Utility Model (RUM) framework (McFadden, 1974). Recent developments in the theory and practice related to the generation and use of SCE have meant that the identified need to firstly, approximate the reality as much as possible in order to increase the behavioural meaning of the results and secondly, to accommodate broader theories of choice behaviour such as aspects ofProspect Theory including the reference dependence assumption, has resulted in the development of SCE designs that are pivoted around individual specific reference alternatives (see, for example, Hensher, 2008; Rose et al., 2008). According to a pivot-design the utility function associated to each hypothetical alternative can then be specified in terms of gains and losses around the reference alternative values, either in terms of absolute levels or percentages. In this context, Hess et al. (2008) highlight the presence of loss aversion identifying asymmetric

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[3] Formally, a reference point under Prospect Theory is assumed to represent the current wealth position of the decision maker (Laury and Holt, 2000). In the transport literature, reference points are typically not defined in terms monetary wealth, but some current situation defined at a given time, reflecting a broader interest than simple gambles typically examined under Prospect Theory. We use this broader definition here, where wealth might be thought of the value in terms of utility related to the entire reference alternative.

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preferences for both time and cost attributes in a car traveller study. Using similar types of experiments, Lanz et al. (2009) tested loss aversion and diminishing sensitivity in an environmental water supply choice experiment, while Masiero and Hensher (2009) did so in a freight transportation framework and also found effects for both time and cost attributes.

In modelling consumer preferences, the marginal rate of substitution plays a fundamental role since it expresses the willingness to pay (WTP), or its counterpart willingness to accept (WTA), for both market and non-market goods. Indeed, in the analysis of travel demand, particular research emphasis has been placed on the estimation of the trade-off between time and cost, commonly referred to as the value of travel time saving (VTTS). The VTTS is of significant importance to transport modellers and planners as it often represents a key input in the evaluation of infrastructure projects (e.g., cost-benefit analysis) or policy measures in general[4]. In this regard, the consistent discrepancy between WTP and WTA measures observed within the literature, where WTP results have been systematically found to be greater than WTA (see Horowitz and McConnell, 2002 for a review), has been shown by Bateman et al. (1997) to be a consequence of loss aversion[5]. According to this evidence, De Borger an Fosgerau (2008) introduce a theoretical model of reference dependence based on the trade-off between travel cost and travel time conditional upon loss aversion and diminishing sensitivity. This same approach has been followed by Hjorth and Fosgerau (2009), which apply a fixed effect logit estimator in order to explain how loss aversion varies with individual characteristics.

Recent advances in discrete choice modelling, typically applied to SCE data, have led to complications in the derivation of the WTP/WTA measures. In particular, the introduction of the mixed multinomial logit (MMNL) model which allows for the estimation of random parameter distributions which reveal preference heterogeneity within a sampled population, has meant that the marginal rates of substitution may become a ratio of two random distributions, namely the coefficient of the attribute of interest over the cost coefficient. Therefore, the resulting WTP/WTA distribution, will follow a distribution that depends on the two distributions specified for the random parameters. In such cases, the resulting distribution may produce a number of undesirable properties, not the least of which are extremely low or large WTP/WTA values[6]. Indeed infinite or near infinite WTP/WTA values may occur where the random parameter associated with the cost attribute is not bounded either side of zero and with undefined moments (see Daly et al., 2009).

In order to overcome this issue, a number of possible solutions have been attempted in the past. The most obvious method is to treat the cost coefficient as a fixed parameter (Revelt and Train, 1998; Hensher et al., 2004). In this case, all values from the random parameter in the numerator are divided by the same value, the cost coefficient, which therefore acts simply as a scaling facture. As such, for models in which the cost coefficient is treated as non-random, the shape of the WTP/WTA distribution will remain the same as the distribution specified for the parameter used in the numerator with only the population moments changing. Other researchers have employed bounded distributions for randomly specified cost coefficients such as log Normal or constrained triangular distributions. In taking this approach, the analyst prevents the cost coefficient taking the value of zero, and hence reduces the possibility of an infinite WTP/WTA

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[4] WTP and WTA have interesting connotations when expressed in terms of VTTS. WTP for time represents how much a decision maker is willing to outlay in order to save some unit of time. WTA on the other hand represents how much money they would have to receive in order to forego time. The receiving of money need not be in the form of a specific transaction, but rather could be represented in the form of a reduction of say a road toll (this is similar to the concept of found money sometimes discussed in the marketing literature).

[5] That is, in a stated choice models that do not take into account preference asymmetry, the ratio of WTA to WTP is equal to one.

[6] For example, the ratio of two normal distributions results in a bimodal distribution. The Cauchy distribution is a special case where both the two means are zero.

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value being observed, however this does not guarantee that the population moments of the resulting distribution are defined (Daly et al., 2009). Unfortunately, such distributions often come at a cost, with log Normal distribution producing large tails (and hence may result in very small WTP/WTA values being observed) and the constrained triangular distribution forcing the spread of the distribution to be a function of the mean (which may not uncover the true extent of any preference heterogeneity that may exist in the sampled population).

The treatment of cost coefficients as fixed or non random parameters over sampled populations represents particularly strong assumption in terms of both scale homogeneity (Train and Weeks, 2005) and taste heterogeneity (Scarpa et al., 2008). The imposition of bounded distributions similarly offer disadvantages and may mask data issues and produce biased WTP/WTA responses if the distributions assumed do not reflect the reality of the data.

An alternative solution to the above problem was proposed by Train and Weeks (2005) through the parameterization of MMNL model not in preference space but rather directly in WTP space[7]. Using this model formulation, the WTP/WTA distributions are estimated directly rather than being estimated post model estimation by taking the ratio of two parameters. In taking this approach, the analyst is able to select directly the appropriate WTP/WTA distribution rather than having limited control over it. In their paper, Train and Weeks (2005) observed a decrease in the amount of heterogeneity in the WTP/WTA estimates to a more behaviourally plausible amount although the model fit was found to decrease. Further papers dealing with different specifications of MMNL model in WTP/WTA space (Scarpa et al., 2008; Mabit et al., 2008; Hensher and Greene, 2009) confirmed the appeal of models estimated directly in WTP space over models in preference space, especially in terms of WTP interpretability and plausibility.

The aim of the paper is to examine the impact of a number of assumptions arising from Prospect Theory on WTP/WTA, in particular *reference dependence*, *loss aversion* and *diminishing sensitivities*. In the current paper, n*on-linear probability weighting*is not addressed, and as such, a full examination of Prospect Theory is not undertaken. In testing the specific selected assumptions arising from Prospect Theory, the purpose is to compare and contrast models estimated in preference and WTP/WTA space. In particular, the objective is to analyse the difference between a MMNL model in preference space with a fixed cost coefficient and a MMNL model estimated in WTP/WTA space with scale heterogeneity in both symmetric and asymmetric specifications. A further objective is to provide further insights into the existence of loss aversion and diminishing sensitivities via an examination of WTP and WTA measures.

The paper is organized as follows. In Section 2, we outline the methodology. In doing so, we discuss the differences between models estimated in preference space and WTP/WTA space. In Section 3 we outline the data used herein before Section 4 presents the model results. Section 5 presents concluding comments for the paper.

2. Mathematical Models of Discrete Choice

Let U_{ntj} denote the utility of alternative j perceived by respondent n in choice situation t. U_{ntj} consists of two components, a modelled component V_{ntj} and an unobserved component ε_{ntj}, such that

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[7] In line with the literature, we refer to such models as being estimated in WTP space rather than WTP/WTA space, although the methods can be readily extended to WTA space. We also note that the intuition of directly estimating the WTP was promoted prior to 2005 (see for example, Hensher, 1976; Cameron and James, 1987).

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$$U_{ntj} = V_{ntj} + \varepsilon_{ntj} \tag{1}$$

As is common practice, we assume the modelled component of utility to be represented as a linear relationship of k and l attributes, x, related to each of the j alternatives and corresponding parameters weights such that

$$U_{ntj} = \lambda_n \left[\beta_{nc} c_{ntj} + \sum_{k=1}^{K} \beta_{nk} x_{ntjk} \sum_{l=1}^{L} \beta_{nl} x_{ntjl} \right] + \varepsilon_{ntj}, \tag{2}$$

where k represents attributes that take values that are worse than some reference point (i.e., travel times that are longer than a current trip) and l attributes that take values that are better (i.e., travel times that are shorter than the same reference point). Given the interest in establishing estimates of WTP/WTA, Equation (2) is separable in price, c_{ntj} and other non price attributes x_{ntjk} and where β_{nk} represents the marginal utility or parameter weight associated with attribute k for respondent n and β_{nk} the marginal utility for the cost attribute c_{ntj}. As well as containing information on the levels of the attributes, x may also contain up to J-1 alternative specific constants (ASCs) capturing the residual mean influences of the unobserved effects on choice associated with their respective alternatives; where x takes the value 1 for the alternative under consideration or zero otherwise. The unobserved component, ε_{ntj}, is assumed to be independently and identically (IID) extreme value type 1 (EV1) distributed. The variance of ε_{ntj} may vary from decision maker n and may be represented as $\mathrm{var}\left(\varepsilon_{ntj}\right) = \dfrac{\pi^2}{6\lambda_n^2}$ which influences the magnitude of the observed component of utility via the scale parameter λ_n.

In writing out the utility function as in Equations (2), the subscript n associated with the parameter weights implies a particular econometric model form will be estimated. In this case, and under the IID EV1 error term assumption, the utility function shown in Equation (2) implies the use of the MMNL model specification framework. The MMNL model allows for the analyst to specify that some or all of the parameter weights estimated be allowed to vary over the sampled population with density $f(\beta_{nk} | \Omega)$. Note that if a parameter is to be treated as non-random, the subscript n will simply cease to be associated with that parameter, as the parameter will be fixed or constant across individuals. Further, where a multivariate Normal distribution is assumed for several random parameters, it is possible to estimate correlated random parameter estimates via a Cholesky decomposition of the random parameter draws (see Train, 2009).

The utility specification provided in Equation (2) represents utility presented in 'preference' space (see Scarpa et al., 2008, Sonnier et al., 2007 or Train and Weeks, 2005). When estimated in the above form, the marginal WTP for attribute k may then be calculated as

$$WTP = \frac{\dfrac{d}{dx_{ntjk}} \lambda_n \beta_{nk} x_{ntjk}}{\dfrac{d}{dc_{ntj}} \lambda_n \beta_{nc} c_{ntj}} = \frac{\beta_{nk}}{\beta_{nc}}. \tag{3}$$

WTA values are similarly calculated by substituting subscript l for k. In order to test specific issues related to prospect theory, a number of adaptations to the utility specification as outlined above are required. In order to test the hypothesis that respondents experience diminishing sensitivity to both gains and losses, it is necessary to apply non-linear transformations to the non-price attributes (a linear price parameter is used in order to allow for a simple comparison between models estimated in both preference and utility space. This assumption could be relaxed

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for models estimated in preference space, however given that models estimated directly estimated in WTP/WTA space use the price parameter as a normalising constant, having a non-linear price attribute and/or different price parameters representing gains or losses is not desirable). For the current paper, a number of attribute transformations were attempted, finally deciding upon a log transformation. Such an attribute transformation does not impact upon any of the discussion related to model estimation, however the WTP calculation shown as Equation (3) now becomes

$$WTP = \frac{\frac{d}{dx_{ntjk}} \lambda_n \beta_{nk} \ln(x_{ntjk})}{\frac{d}{dc_{ntj}} \lambda_n \beta_{nc} c_{ntj}} = \frac{\beta_{nk} \frac{1}{x_{ntjk}}}{\beta_{nc}}. \tag{4}$$

It is possible to re-specify the utility function so as to estimate the WTP/WTA estimates directly. To do this, Equation (2) may be re-arranged as follows.

$$U_{ntj} = \lambda_n \left[c_{ntj} + \frac{1}{\beta_{nc}} \sum_{k=1}^{K} \beta_{nk} x_{ntjk} + \sum_{l=1}^{L} \beta_{nl} x_{ntjl} \right] + \varepsilon_{ntj},$$

$$= \lambda_n c_{ntj} + \lambda_n \left[\sum_{k=1}^{K} \theta_{nk} x_{ntjk} + \sum_{l=1}^{L} \beta_{nl} x_{ntjl} \right] + \varepsilon_{ntj}. \tag{5}$$

Further, by directly modelling the marginal rate of substitution instead of the marginal utility an assumption is made that the respondent has a reference WTP/WTAother than a reference preference[8]. Other studies are based on the concept of reference WTP, see for example, De Borger and Fosgerau (2008); Hjorth and Fosgerau (2009). Indeed, the reference WTP/WTA measures are easily obtained by specifying reference specific coefficients in the utility function. Therefore, instead of working with deviations from the reference point (as in Hess et al., 2008; Lanz et al., 2009; Masiero and Hensher, 2009) the model is specified using the absolute values of differences in order to allow the parameters for reference alternative to be estimated. The difference from the reference point is then computed in terms of marginal utilities.

In order to order to operationalise the model, we use a restricted form of the GMNL model (see Fiebig et al., 2010 and Greene and Hensher, 2010). In estimating the model, λ_n takes the form

$$\lambda_n = e^{\left(\bar{\lambda} + \tau w_n\right)}, \tag{6}$$

where w_n is an individual specific random draw from a truncated Normal distribution. Fiebig et al. (2010) and Greene and Hensher (2010) note that depending on the estimate of τ, extremely large values of λ_n can occur depending on the values drawn from w_n and when such large values are observed, software overflows may occur and the estimator becomes unstable. The current paper applies the approach suggested by Greene and Hensher (2010) which directly restricts the values of w_n to be between ±1.96 by setting $w_{nr} = \Phi^{-1}\left[0.025 + 0.95U_{nr}\right]$ where the value of w_n for the rth draw is calculated from the inverse of the standard normal cumulative distribution function, $\Phi^{-1}\left[.\right]$ given a random draw from a standard uniform distribution bounded by 0 and 1. This contrasts to the approach of Fiebig et al. (2010) who simply truncate draws at ±2.

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[8] That is, the respondent has a specific monetary value that they have placed upon the current reference alternative rather than simply a general preference for it.

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Given that λ_n and θ_{nk} enter Equation (5) as a product, $\lambda_n \theta_{nk}$ some normalization λ_n is required in order to estimate θ_{nk}. The normalization used here is to set the mean of λ_n to 1.0. To do this, the estimated model assumes

$$E[\lambda_n] = e^{\left(\tau^2/2 + \tau w_n\right)}. \tag{7}$$

3. Empirical data

Data for the current study was collected in Sydney in 2004 as part of a wider study designed specifically to obtain estimates of the VTTS for car drivers in the Sydney metropolitan area. For this study, models are estimated only on the commuting data segment, ignoring data dealing with non-commuting trips. Respondents were drawn from those in the population who had recently taken a trip along a route which could possibly have involved travelling along a proposed toll road to be built sometime in the future. Respondents were recruited using a computer aided telephone interview (CATI) with eligible respondents being drawn from households that were stratified geographically within a large catchment area. Once recruited, a time and location was agreed upon for the survey to be undertaken using a face-to-face computer aided personal interview (CAPI). Quotas were imposed to insure a range of travel times over the sample; between 10 and 30 minutes, 31 to 60 minutes, and more than 61 minutes (capped at two hours).Trips of less than 10 minutes were excluded for both practical and theoretical reasons. From a practical perspective, it was felt that varying travel times and costs around a small base was not likely to produce levels which would be liable to induce a change of route in reality (e.g., a 10 percent reduction in a travel time of two minutes is only 1.48 seconds, a saving of only 12 seconds). Secondly, within the Sydney context, shorter travel times are unlikely to attract road user charges, although this situation may be different in other cities, and may change in Sydney given advances in future technology.

Once recruited, respondents were asked information about their current trip to frame the context of the experiment. Based on the actual trip reported, respondents were given 16 choice scenarios. The first alternative represented the respondent's current reported trip (a RP alternative) with the remaining two alternatives representing competing hypothetical routes (SC alternatives). The two SC alternatives represent unlabelled routes. The trip attributes associated with each route are free flow time, slowed down time, trip travel time variability, vehicle running cost (essentially fuel) and the toll cost. These were identified from reviews of the literature and supported by the effectiveness of previous VTTS studies undertaken by Hensher (2001). In addition, previous studies were used to establishing the priors (i.e., parameter estimates associated with each attribute) for designing the experiment. All attributes of the SC alternatives are based on the values of the current trip. Variability in travel time for the current alternative was calculated as the difference between the longest and shortest trip time provided in non-SC questions. The SC alternative values for this attribute are variations around the total trip time. For all other attributes, the values for the SC alternatives are variations around the values for the current trip. The variations used for each attribute are given in Table 1.

Over the course of the experiment, the RP alternative was invariant across the 16 choice situations with only the levels of the SC alternatives changing. Before commencing, respondents were given an example game to practice with. An example choice situation (taken from a practice game) is shown in Figure 1.

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Table 1. Profile of attribute ranges in the SP design

	Free-flow time	Slowed down time	Variability	Running costs	Toll costs
Level 1	- 50%	- 50%	+ 5%	- 50%	- 100%
Level 2	- 20%	- 20%	+ 10%	- 20%	+ 20%
Level 3	+ 10%	+ 10%	+ 15%	+ 10%	+ 40%
Level 4	+ 40%	+ 40%	+ 20%	+ 40%	+ 60%

The experimental design has three versions (one for each trip segment) of 16 choice sets (games). The design has no dominance given the assumption that less of all attributes is better (for a discussion on the generation of experimental designs, see e.g., Bliemer and Rose, 2009 or Rose and Bliemer, 2009). The distinction between free flow and slowed down time is designed to promote the differences in the quality of travel time between various routes – especially a tolled route and a non-tolled route, and is separate to the influence of total time. Free flow time is interpreted with reference to a trip at 3am when there are no delays due to traffic.[9]

The final sample consisted of 300 respondents, representing 4,800 choice observations. Of these 300 respondents, six respondents (representing 96 choice observations) always choose the current RP alternative irrespective of the attribute levels shown in the two SC alternatives. For this paper, these six respondents were removed from the analysis, leaving data from 294 respondents (4,704 choice observations) from which to model. Further details of the sampling frame and response rates for the sample are provided in (Hensher and Rose, 2004)

Figure 1. An example of a stated choice screen

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[9] This distinction does not imply that there is a specific minute of a trip that is free flow per se but it does tell respondents that there is a certain amount of the total time that is slowed down due to traffic, and hence that a balance is not slowed down (i.e., is free flow, like one observes typically at 3am).

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4. Model Results

Table 2 summarizes the results of six estimated models. Models were estimated in Nlogit 4.0 using 1,000 Halton draws per random parameter (see Train, 2003). Model 1 (M1) represents the base MMNL model estimated in preference space whilst Model 4 (M4) represents the equivalent model estimated in WTP/WTA space. Model 2 (M2) and 3 (M3), both estimated in preference space, allow for different marginal utilities for gains and losses. M3 differs to M2 in that M3 applies a log transformation to the free flow and slowed down time attributes. Models M5 and M6 are the equivalent models to M2 and M3 respectively, only estimated in WTP/WTA space.

The utility specification for the base model M1 is shown in Equation (8) whilst the specification for model M2 is provided in Equation (9).

$$V_{ntj} = \delta_{reference}Ref + \delta_{SC1}SC_1 + \lambda_n \lfloor \beta_{nC}c_{nt} + \beta_{ff}FF_{nt} + \beta_{sdt}SDT_{nt} \rfloor, \tag{8}$$

$$V_{ntref} = \delta_{reference}Ref + \lambda_n \lfloor \beta_{nC}c_{nt} + \beta_{ff}FF_{nt} + \beta_{sdt}SDT_{nt} \rfloor,$$

$$V_{nt,sc1,sc2} = \delta_{SC1}SC_1 + \lambda_n \begin{bmatrix} \beta_{nC}c_{nt} + \beta_{ff-loss}FF_{loss} \\ + \beta_{ff-gain}FF_{gain} + \beta_{sdt-loss}SDT_{loss} + \beta_{sdt-gain}SDT_{gain} \end{bmatrix}, \tag{9}$$

where *ref* and SC_1 are dummy variables associated with the reference and first SC alternative, *FF* and *SDT* are the free-flow time and slowed down timesof the reference (or recent trip which was captured as the revealed preference alternative in the survey) and X_{loss} and X_{gain} represent the absolute difference between a time attribute shown in the reference alternative and the time shown in the SC alternative. The utility specification for model M3 is similar to that shown in Equation (9), however the model uses the logs of X_{loss} and X_{gain} rather than the actual values themselves. For models M1 to M3, the scale parameter, λ_n is normalised to 1.0 as typical of MMNL models (see Train, 2003). Models M4to M6 are equivalent to models M1 to M3 respectively however the cost parameter is normalised to 1.0 and the scale parameter is estimated.

In terms of testing the relevant aspects of Prospect Theory, models M2, M3, M5 and M6 allow us to test the hypothesis that individuals experience loss aversion, whereas models M3 and M6 also allow us to explore whether they also experience diminishing sensitivity to both gains and losses. Note that given the experimental design applied, the travel time variability attribute only was presented to respondents simply as ± some value from the reference, rather than a plus in some games and a minus in others. As such, a test of the specific aspects of Prospect Theory that are of interest to this paper could not be performed on this attribute as it simultaneously represents both a gain and a loss, and hence it is excluded from the final models estimated.

Presented at the base of Table 2 are the model fit statistics. Two sets of overall goodness to fit statistics have been provided. The first compares the final model against the log-likelihood for a base model assuming all parameters are simultaneously equal to zero (i.e., $\rho^2(0)$). The second model fit statistic is against a model estimated allowing for alternative specific constants only (i.e., $\rho^2(ASC)$). Comparing the adjusted $\rho^2(ASC)$ values, which correct for differences in the number of parameters estimated from each of the models, the best model fit for the data is associated with model M4. This finding contradicts the findings of other researchers who have found that models estimated in WTP space typically produce worse model fits (see e.g., Scarpa et al., 2008, Sonnier et al., 2007 or Train and Weeks, 2005). Further, comparing models that are equivalent in how the attributes have been treated in their utility specifications (i.e., M1 to M4, M2 top M5 and M3 to M6), it is worth noting that the WTP/WTA models statistically outperform

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Table 2. Model Results

	M1 (Pref. Space MMNL)		M2 (Pref. Space Pros.		M3 (Pref. Space Log Pros.		M4 (WTP/WTA Space		M5 (WTP/WTA Space		M6 (WTP/WTA Space	
	Par.	(*t*-ratio)	Par.	(*t*-ratio)	Par.	(*t*-ratio)	Par.	(*t*-ratio)	Par.	(*t*-ratio)	Par.	(*t*-ratio)
Random parameters												
Free flow time (mean)	-0.081	(-11.32)	-0.064	(-6.12)	-0.060	(-5.13)	0.264	(37.12)	0.093	(3.25)	0.042	(2.40)
Free flow time (std dev.)	0.089	(12.64)	0.062	(5.16)	0.054	(5.74)	0.248	(54.41)	0.230	(7.41)	0.158	(6.03)
Slowed down time (mean)	-0.102	(-16.36)	-0.043	(-4.30)	-0.037	(-2.58)	0.346	(64.07)	0.032	(1.41)	0.012	(1.07)
Slowed down time (std dev.)	0.078	(9.27)	0.042	(6.68)	0.027	(2.00)	0.213	(36.48)	0.052	(1.75)	0.039	(2.59)
Free Flow time gain (mean)	-	-	0.046	(4.58)	0.286	(4.21)	-	-	-0.208	(-5.08)	-0.477	(-2.34)
Free flow time gain (std dev.)	-	-	0.077	(6.31)	0.457	(3.67)	-	-	0.260	(6.68)	0.988	(4.16)
Free flow time loss (mean)	-	-	-0.244	(-8.44)	-0.849	(-8.64)	-	-	0.937	(7.39)	1.985	(7.43)
Free flow time loss (std dev.)	-	-	0.186	(5.57)	0.685	(2.82)	-	-	0.903	(6.78)	1.022	(1.87)
Slowed down time gain (mean)	-	-	0.086	(10.39)	0.657	(9.26)	-	-	-0.362	(-8.81)	-1.526	(-5.29)
Slowed down time gain (std dev.)	-	-	0.060	(3.90)	0.553	(4.08)	-	-	0.255	(6.26)	1.558	(5.09)
Slowed down time loss (mean)	-	-	-0.286	(-11.61)	-1.006	(-10.96)	-	-	1.137	(9.51)	3.038	(6.46)
Slowed down time loss (std dev.)	-	-	0.198	(3.23)	0.791	(2.16)	-	-	0.993	(7.15)	2.763	(7.45)
Non-Random parameters												
Constant (reference alt.)	-0.111	(-2.34)	1.191	(4.11)	0.908	(2.77)	-0.116	(-3.85)	-0.958	(-4.90)	-0.611	(-5.59)
Constant (SP alt 1)	0.158	(3.30)	0.155	(3.23)	0.130	(2.72)	0.152	(4.13)	0.160	(3.22)	0.170	(3.95)
Cost	-0.338	(-31.78)	-0.244	(-25.97)	-0.237	(-25.79)	-	-	-	-	-	-
Scale Parameter												
Variance Parameter in Scale (τ)	-	-	-	-	-	-	0.947	(32.30)	0.382	(1.93)	0.511	(2.23)
Sigma Parameter												
Sample Mean	-	-	-	-	-	-	1.486	-	1.388	-	2.014	-
Sample Std Dev.	-	-	-	-	-	-	2.523	-	1.489	-	4.185	-
Model Fits												
LL(0)	-5167.872		-5167.872		-5167.872		-5167.872		-5167.872		-5167.872	
LL(ASC)	-5151.471		-5151.471		-5151.471		-5151.471		-5151.471		-5151.471	
LL(β)	-3589.897		-3756.572		-3815.333		-3349.851		-3622.293		-3791.076	
K	10		36		36		12		45		45	
$\rho^2(0)$	0.305		0.273		0.262		0.352		0.299		0.266	
Adj. $\rho^2(0)$	0.304		0.267		0.256		0.350		0.292		0.259	
$\rho^2(ASC)$	0.303		0.271		0.259		0.350		0.297		0.264	
Adj. $\rho^2(ASC)$	0.302		0.265		0.254		0.348		0.290		0.257	
Number of Respondents	294											
Number of Observations	4704											

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their equivalent preference space models in each instant as shown in Table 3 which shows the log-likelihood ratio test.

It is also worth noting that the simple linear specification of utility rather than those that allow for loss aversion as well as for diminishing sensitivity to both gains and losses appear to perform better in terms of model fits. Comparing the model fits only for the models that allow a test of the aspects that of interest of Prospect Theory, we find that both in preference space and WTP/WTA model forms, allowing for diminishing sensitivity to both gains and losses results in lower model fits, at least insofar as the correct attribute transformation can be assumed to have been applied. This finding contradicts the findings of Hess et al. (2008) estimated on the same data who found that models allowing for asymmetrical preferences produced better model fits. Unlike Hess et al. (2008), the current utility specification requires symmetrical preferences for the cost attributes. This suggests that the preference asymmetry resident within the data exists predominately for the cost attributes as opposed to the time attributes.

Table 3. Log-likelihood ratio tests

Model comparison	χ^2	χ^2 critical value
M1-M4	480.092	5.991
M2-M5	268.558	16.919
M3-M6	48.514	16.919

Each of the models allow for correlated random parameters via the inclusion of the Cholesky matrix (for reasons of space, these parameters are not shown, however the full model results are available from the authors upon request). The parameters associated with this matrix supports the fact that there does exist some form of correlation amongst the random parameter estimates, although the correlation structure revealed appears to change depending upon the utility specification and model form imposed. Nevertheless, the several significant parameters for the Cholesky matrix indicate that a specification that does not allow for such correlation would be inappropriate. As such, failure to allow for such correlations in the modelling may result in biased parameters, and more importantly, incorrect inferences as to the relationships held in terms of the preferences and WTP/WTA by individual respondents.

Examining the scale parameters (i.e., τ) for each of the WTP/WTA space models reveals that the parameter is highly significant for the non-prospect theory model (M4), statistically significant at the 0.06 percent level for model M5 and statistically significant at the 0.05 percent level for model M6. This suggests that scale heterogeneity exists in each model after accounting for correlation between the random parameters themselves. To breakdown this observed scale heterogeneity, the estimated models further allow for correlation between the random scale term and the random parameters. Once more, varied evidence exists across the three WTP/WTA models of such correlation.

Turning to the parameter estimates for free flow time and slowed down time, all parameters are of the expected sign and relative magnitude, although there exist significant levels of heterogeneity within the sample. As is to be expected, comparing the parameter estimates for the preference space models allowing for differences in losses and gains, it is found that relative to the reference alternatives, the parameters related to gains are positive compared to the parameters associated with losses which are negative. Examining the absolute value of the magnitudes of the (mean) gain and loss parameter estimates, the magnitude of the loss parameters is larger than those for the gains, providing supporting evidence of respondents, on average, having experienced loss aversion when completing the SC survey. Given a negative price parameter means that models estimated in WTP/WTA space should produce opposite

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signs for the non price parameters to those estimated in preference of the parameter estimates, one would expect that the WTP/WTA parameters for losses will be positive relative to the reference base and gain parameters to be negative. Examining Models M5 and M6, this is precisely what is observed where once more the relative absolute magnitudes of the gains and losses (at least for the mean of the random parameter distribution) conform with expectations if *reference dependence*, *loss aversion* and *diminishing sensitivities* are true.

The main focus of the paper is to compare and contrast models estimated in preference space to those estimated in WTP/WTA space allowing for asymmetry in the marginal utilities for gains relative to losses. Figure 2 plots the WTP/WTA distributions for models M2, M3, M5 and M6. In order to construct confidence intervals around the individual WTP/WTA measures, the Krinsky and Robb procedure (Krinsky and Robb, 1986, 1990) is employed to simulate the distributions. The Krinsky and Robb procedure is useful for constructing WTP/WTA confidence intervals in that it accounts not only for the population moments of the random parameter distributions in simulating the WTP/WTA distributions, but also accounts for the standard errors and covariances of each of the estimated parameters. Examination of the plots provides supporting evidence for the two primary hypothesised effects of prospect theory; that individuals experience loss aversion, as well as that they also experience diminishing sensitivity to both gains and losses (resulting, for models M3 and M4, in the asymmetric s-shape functional form hypothesised by prospect theory). Finally, it is also interesting to note the capability of a specification in WTP/WTA space to contain the spread of the confidence intervals around the individual WTP/WTA measures. The result is particularly evident for model M6, which is the equivalent in WTP/WTA space of model M3. This evidence supports the previously noted advantage of estimating models directly in WTP/WTA space, particularly over models estimated in preference space using non random price parameters, in avoiding the undesirable complications associated with WTP measures derived from ratio distributions. Nevertheless, the shape of the confidence intervals for the log models show serious implications for generating such intervals for models with log transformed attribute, despite such transformations representing the most sensible approach to test for loss aversion and diminishing sensitivity effects.

Table 4 provides estimates of the WTP and WTA for each model calculated assuming a 20 minute gain or loss relative to the reference trip time. Given that the model estimates are random parameters, we have calculated these at the means of the random parameter distributions only. Also shown in Table 4 are the ratios of the gains and losses for each model. The ratios of for WTA to WTP range between 1.97 to 3.74 which are largely consistent similar ratios found by Boyce et al. (1992) and Horowitz and McConnell (2002) who found a median ratio 2.6. This provides some evidence of the plausibility of the current findings. Note however, that it is necessary to assume a specific value for time in the current context (as we did here assuming 20 minutes) as the WTP/WTA values obtained for the log transformed models will vary with time. As such, so too will the ratios of WTA to WTP.

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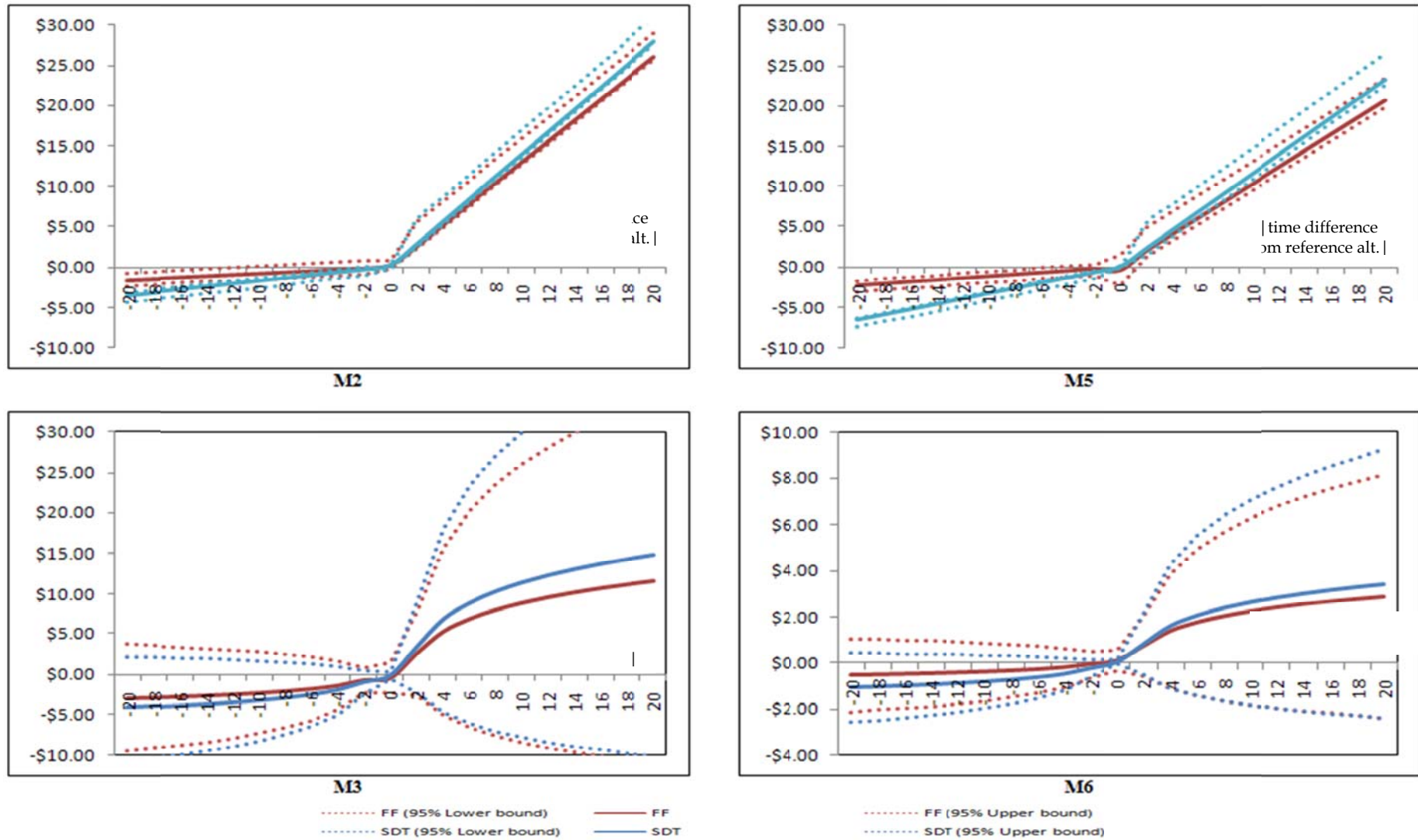Estimated in Preference and WTP/WTA Space

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Figure 2. WTP plots

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Table 4. WTP/WTA results (AUD/min, normalized at 20 minutes)

	Symmetric models (M1) and (M4)	Asymmetric Linear (M2) and (M5)	Asymmetric Nonlinear (log) (M3) and (M6)
Free-flow time			
Preference space	WTA = $4.79 WTP = $4.79 Ratio = $1.00	WTA = $25.25 WTP = $9.02 Ratio = 2.80	WTA = $11.49 WTP = $4.37 Ratio = 2.63
WTP/WTA space	WTA = $5.28 WTP = $5.28 Ratio = 1.00	WTA = $16.88 WTP = $6.02 Ratio = 2.8	WTA = $5.82 WTP = $1.55 Ratio = 3.74
Slowed down time			
Preference space	WTA = $6.04 WTP = $6.04 Ratio = 1.00	WTA = $26.97 WTP = $10.57 Ratio = 2.55	WTA = $13.18 WTP = $8.77 Ratio = 1.50
WTP/WTA space	WTA = $6.92 WTP = $6.92 Ratio = 1.00	WTA = $22.10 WTP = $7.88 Ratio = 2.80	WTA = $9.07 WTP = $4.61 Ratio = 1.97

5. Conclusions

This paper has investigated MMNL models estimated in both preference and WTP/WTA space under various assumptions that are derived under prospect theory; namely loss aversion and diminishing sensitivities to gains and losses. The comparison of the two main approaches was based on the estimation of three different pairs of models. Firstly, the estimation of a model specified using a classic symmetric model which provided a basic comparison between models estimated in preference and WTP/WTA space. Secondly, according to reference dependence theory, an alternative model was specified where different parameters for gain and loss values relative to individual specific reference cases through an asymmetric linear specification in both preference and WTP/WTA space models. The third pair of models allowed for asymmetric nonlinearity in the utility function using a log transformation of the non-price attributes. The resulting six models were tested using data collected in Sydney in 2004 within a stated choice experiment study aimed at obtaining estimates of the VTTS for car drivers.

The comparison between models in preference and WTP/WTA space suggest an overall and significant improvement in the model fit when the data are estimated in WTP/WTA space rather than preference space (in both symmetric and asymmetric specifications). This evidence contrasts with previous findings that models estimated in WTP/WTA space typically produce worse model fits (see for example, Train and Weeks, 2005; Hensher and Greene, 2009). However, Scarpa et al. (2008) show that the specification in WTP/WTA space can statistically outperform its equivalent in preference space when using revealed preference data. Indeed, results might be affected by the different nature of the dataset used (stated versus revealed preference) or even by the different context of the study. Since the literature in discrete choice models estimated in WTP/WTA space is still limited, further studies are needed in order to support these findings.

The results obtained from the parameters associated with gains and losses are statistically significant and coherent with loss aversion and diminishing sensitivity assumptions, in both preference and WTP/WTA space models. Nevertheless, according to the model fits, the symmetric specifications are preferred to the reference dependence specifications. This is

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unexpected since previous studies report increases in the model fit consistently with the statistically significance of the reference dependence specifications (see for example, Hess et al., 2008; Masiero and Hensher, 2009). A possible explanation might be that we do not consider the cost parameter as asymmetric as in previous studies. Unfortunately, this constraint was necessary in order to allow for a full set of comparisons between preference and WTP/WTA space models using a reference dependence utility specification.

In terms of policy implications, the results presented here provide support for the need for policy makers to make correct decisions in terms of pricing to the public the user costs for transport infrastructure. Once prices, such as public transport fares or road tolls have been established, the specific value will become the reference point for travellers. If the initial price is set too low, then attempts to raise the price at a later stage will have a smaller impact in terms of preferences and WTP than setting the price too high initially and lowering costs (an empirical example of this was the experience of the Cross City Tunnel in Sydney Australia which changed toll prices several times in the first year of its opening as a result of media and political pressure, resulting in depressed demand). Further, the results presented here also have implications in terms of how WTP/WTA are used in wider network wide models. Typically WTP are used in such models, either via some form of generalised cost conversion or directly in mode or route choice models. Failure to account for the effects demonstrated in this and other papers may result in incorrect inferences being drawn from such models. Unfortunately, including these types of results in such models is far from a non-trivial task at the present time.

Finally, further insights are providedadding to the growing topic of discrete choice models linked to Prospect Theory assumptions. Furthermore, the results show that the combination of a reference dependence specification with a model in WTP/WTA space decreases the plausibility of the WTP/WTA measures and captures the divergence in between WTA and WTP, however once more this finding is likely to be the result of greater asymmetry existing with the cost attributes which we have necessarily forced to be constant in the model specification. We encourage further research in the investigation of models in WTP/WTA space that could encompass the considerable potential of a reference dependence utility specification.

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